SCIENCE FOR CERAMIC PRODUCTION

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PRODUCTION OF FACING BRICK BY PLASMA TREATMENT USING RAW MATERIAL FROM TECHNOGENIC DEPOSITS

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The production of facing brick by plasma treatment combined with technological operations of softening roasting and spray-coating of decorative material based on technogenic raw material is examined. A unified nomenclature of quality indicators for wall (facing) ceramic is developed.

In housing construction, a great deal of importance is now placed on the exterior finishing of buildings and the longevity and quality of the facing materials and their architectural expressivity. Plasma treatment of the facing surface of structural materials is one of the most effective treatments, since it conserves resources and energy. Plasma technology is ecologically clean because it uses argon gas to form the plasma. The high plasma temperatures (7000 – 10,000 K) greatly intensify the processes leading to the formation and accumulation of a glass phase in the surface layers of the ceramic being treated, including the facing surface of structural materials. As a result, the treatment time is shorter than for conventional technology.

The present article presents the results of investigations of glazing on wall ceramic using powders based on raw material from technogenic deposits. Wastes from enrichment of KMA iron quartz, from claydite production, and from the production of ceramic sanitary ware were used for glazing. The chemical composition of the waste is presented in Table 1.

A number of investigations have shown that powders with grain size 10 – 250 μm are optimal for plasma spraying [1, 2]. We used the 60 – 250 μm fraction of KMA wastes for plasma spraying. Other production wastes were first milled in ball mills with uralite balls and sieved in sieves with cell sizes corresponding to plasma spraying technology.

The UPU-8M serially produced plasmatron was used for plasma treatment. The operational parameters of the plasmatron were as follows: working voltage 30 – 32 V and current strength 350 – 450 A. Argon serves as the plasma form the gas; its flow rate was 2.5 m^3/h at pressure 0.25 MPa. The flow rate of the water cooling the GN-5r plasma burner was 10 – 12 liters/min. The Saha equation was use to calculate the temperature of the plasma flame [3]. The calculations show that the mass-average temperature of the plasma flame with current strength 350 – 450 A and argon flow rate 2.5 m^3/h is 7800 – 8600 K.

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TABLE 1.

Wastes	Mass content, %									
	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	SO_3	calcination loss
KMA iron quartz enrichment*	66.19	9.51	9.06	6.44	3.70	4.08	0.69	0.51	0.16	5.19
Claydite production**	70.51	12.23	4.03	1.20	6.13	0.70	0.25	1.14	Traces	4.12
Ceramic sanitary ware production	65.15	25.98	0.30	–	0.53	0.36	1.05	0.60	″	6.92

* P_2O_5 content 0.11%.

** TiO_2 content 0.72%.

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Several technological schemes of plasma treatment of all ceramics are now known [2]:

direct plasma melting of the facing surface of the wall ceramic;

plasma melting of the facing surface of wall ceramic followed by spraying of glazing powder and air cooling of the melt;

plasma melting of dried intermediate articles followed by technological firing.

The second technological scheme is most suitable in our case. It incorporates plasma melting and subsequent spraying of the powder glaze by an air stream. However, this method has the following drawbacks:

there are two stages in the technology for a obtaining a glaze layer: obtaining melt on the surface of the wall ceramic and depositing the glaze powder on it in air;

an air nozzle is used in addition to the plasma burner;

high energy consumption.

To eliminate these drawbacks we developed a technology which incorporates plasma melting of the facing surface of wall ceramic together with deposition of powder from technogenic deposits.

The optimal parameters to be technology developed are as follows:

the distance from the GN-5r plasma burner cut-off to the facing surface of the wall ceramic is 10 – 12 mm;

the travel rate of the plasma burner along the facing surface of the wall ceramic is 1.8 – 2.2 cm/sec;

the consumption rate of the waste powder is 1.2 – 1.3 g/min;

the thickness of the decorative layer is 800 – 1100 μm.

Combining the operations of plasma melting and spraying makes it possible to decrease the consumption of energy and increase the efficiency of facing brick production, which makes the product more competitive.

Samples with dimensions $50 \times 50 \times 50$ mm based on clay from the Krasnoyarsk deposit were used in the experiments. These samples prepared by plastic deformation were tried and fired in a muffle furnace at 1000°C with a holding time of 2 h at the maximum temperature. A serial commercial batch of samples of standard ceramic solid- and hollow-body bricks with dimensions $65 \times 120 \times 250$ mm was also treated by a plasma flame under industrial conditions at the production sites of PLAZMIKA JSC (Belgorod). The capacity of the production line was 520 articles/h and the energy consumption was 1.5 kW · h/m^2.

The experiments showed that in the case of plasma melting and deposition of wastes from enrichment of KMA iron quartz a black glaze layer with even pouring is formed on the facing surface of the wall ceramic, and for plasma spraying of wastes from claydite production a light green (emerald) glaze layer is formed. Wastes from ceramic sanitary ware production gave a glaze layer with an ivory color.

Thus, using various industrial waste materials as glazes, decorative coatings with a diverse color range were obtained. These coatings consist of glass with high operational and aesthetic indicators.

The fundamentally new technology developed for producing facing glazed ceramic using alternative sources of energy made possible to obtain high-quality product with a new set of user properties. To assess its level of quality and competitiveness, it was necessary to develop a nomenclature of user properties for this group of wall glaze construction materials.

A nomenclature of user properties of wall (facing) ceramic was developed on the basis of the investigations performed in this work. The functional, ergonomic, aesthetic, and ecological properties as well as reliability and safety were classified as first-level indicators. We shall examine in greater detail the complex and single quality indicators (Table 2).

The functional indicators of wall ceramic are characterized by, first and foremost, the compression and bending strength. The methods for determining the ultimate strength under compression and bending are stipulated in GOST 8462–85.

The heat protection properties of wall ceramic are determined by the requirements in GOST 530–95 and are characterized by indicators such as the thermal conductivity.

The reliability of wall (facing) ceramic can be characterized by longevity and preservability. Brick used in Central Russia, Western Siberia, and the Far East is subjected to cycles of freezing and thawing and to prolonged heat cycling. In this connection, we propose that heat resistance be added to the longevity group in addition to resistance to cold. The microhardness of the facing surface of wall ceramic can be characterized by the resistance of an article to impact loads and scratching. For this reason, it was suggested that this indicator be included in the reliability group. A 5% difference between the CLTE of the ceramic base and the glaze layer results in the appearance of substantial stresses in a coating and decreases its strength. Thus, the CLTE of a glaze layer and a ceramic can determine the longevity of the facing layer of a wall ceramic.

The preservability is characterized by the chemical resistance of the ceramic material itself and of the facing glazed layer. Water, acid, and alkali resistance appear here.

The ergonomic indicators of the wall (facing) ceramic can be determined by complex indicators, such as hygienic quality. We propose that this indicator be characterized by the following single indicators: proneness to become dirty, porosity of the ceramic and decorative coating, and water absorption of the ceramic. The proneness to soiling can be characterized by the adhesion of contaminants with the facing surface of the wall ceramic and the porosity of the ceramic.

The aesthetic indicators of the wall (facing) ceramic have a quite specific character and can be determined by the trade type of the article itself and the quality of the facing surface. Thus, the following were included in the group of aesthetic indicators: composition integrity, production perfection, and stability of the exterior appearance. We propose that the in-

TABLE 2.

First-level indicators	Complex indicators	Single indicators
Functional	Basic-function performance indicators	Compression and bending strength Adhesion strength of glaze layer Ceramic density Decorative coating density Thermal conductivity Water absorption by ceramic
Reliability	Longevity	Resistance to cold Microhardness of decorative (glaze) coating CLTE of glaze layer and ceramic Heat resistance of decorative coating
	Preservability (chemical stability)	Water resistance of decorative coating Acid and alkali resistance of decorative coating and ceramic base
Ergonomic	Hygienic	Porosity of ceramic and decorative coating
Aesthetic	Composition integrity	Surface texture Color of decorative coating Brightness (dullness) of decorative coating Ceramic color Refractive index of coating
	Production perfection and exterior-appearance stability	Sharpness of shape and faces Ceramic color uniformity Decorative coating thickness
Ecological	Radiation safety	Radioactive background Content (concentration) of radioactive elements
Safety	Flame resistance (heat resistance)	Meltability of glaze layer
	Mechanical safety	Article mass

tegrity of the composition of the wall (facing) ceramic be characterized by the brightness (dullness) and texture of the facing surface and by the color of the ceramic brick itself.

The production perfection and stability of the exterior appearance of articles can be determined by the sharpness of the shape and faces of the brick, the color uniformity of the ceramic, and the thickness of the decorative facing coating.

The ecological indicators are characterized by radioactivity safety. In accordance with GOST 530–95, the specific effective activity of natural radionuclides and wall ceramic should not exceed 370 Bq/kg.

Fire resistance (heat resistance) and mechanical safety can be classified as safety indicators. According to GOST 30244–94, ceramic bricks and stones are classified as inflammable construction materials. Fire resistance is characterized by the meltability of the ceramic and the glaze layer. The mechanical safety is determined by the mass of the article itself. In accordance with GOST 530–95, the mass of brick in a dried state should not exceed 4.3 kg and the mass of ceramic stones should not exceed 16 kg.

Our investigations made it possible to develop an effective energy and resource conserving technology for producing facing brick. Facing brick meets the requirements of GOST 530–95 for strength and cold resistance. The strength of the adhesion of a glaze layer to ceramic reached 3.8 MPa, which is 0.5 – 1.5 MPa higher than the strength of adhesion of a glaze layer to a substrate obtained using previously known technologies for glazing and coating of the main ceramic using a low-temperature plasma flame.

In contrast to other forms of ceramic on the wall (facing) ceramic materials, at present there are no standards for the system of product quality indicators, for example, porcelain – faience articles. In this connection, a unified nomenclature for quality indicators can be used to develop a corresponding standard and estimate the quality and competitiveness of wall (facing) construction materials and for new types of materials for production and operation.

Facing brick technology using plasma treatment, where melting and deposition of a decorative material based on technogenic wall material are combined, is recommended as a resource and energy conserving technology for wide commercial adoption.

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